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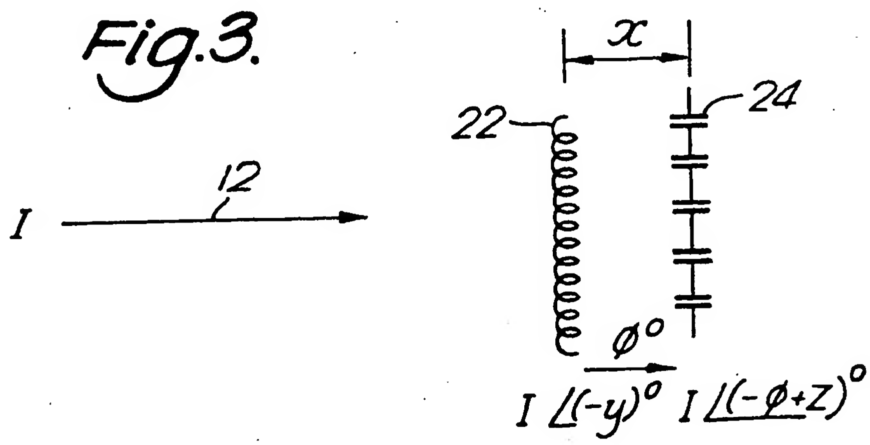
(54) Low scattering structure

(57) A structure having controllable scattering when excited by an incident electromagnetic field (I) comprises a pair of conductive elements (22, 24) extending substantially parallel and mounted in a support structure. One of the elements (22) has a largely inductive impedance and the excitation current induced in the element (22) has a phase lag (y°) compared to the phase of the incident wave (I). The second element (24) has a largely capacitive impedance and the excitation current induced has a phase lead (Z°) compared with the incident field (I). By control of the impedance characteristics of the two conductive elements (22, 24) the energy radiated by the excited conductive elements can be minimised in a pre-selected direction to reduce the disturbance caused to the incident wave and prevent detection of the structure due to changes in the uniformity of the incident wave. The inductive element (22), being a continuous conductor, may be used to provide an antenna element or feed structure having controlled scattering.

Fig.3.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1.

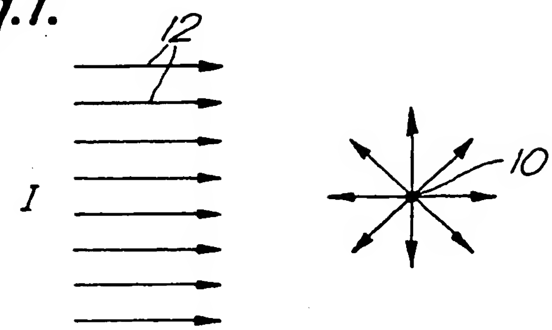


Fig.2.

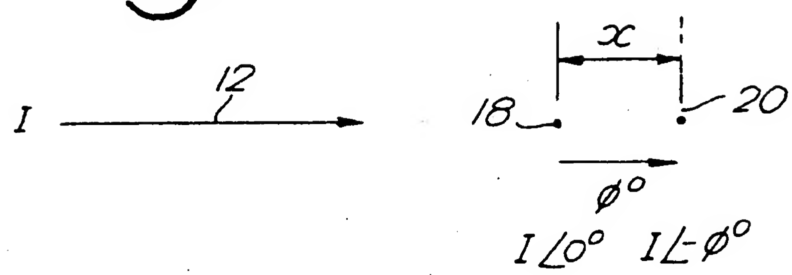


Fig.3.

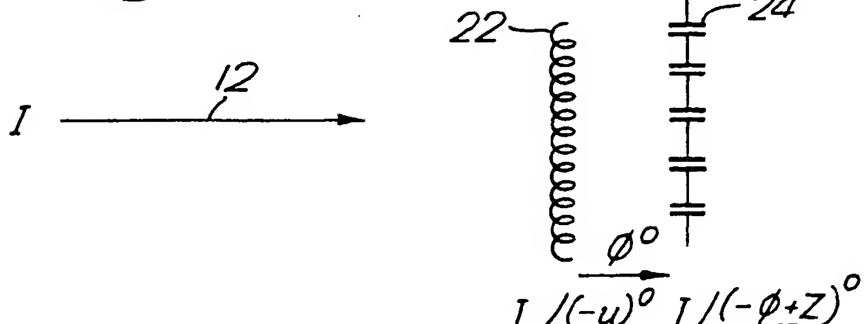


Fig.4.

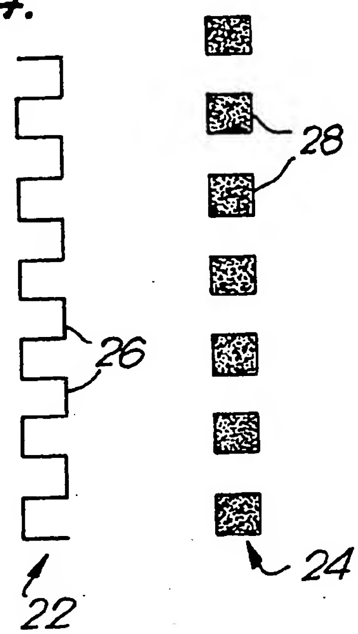


Fig.5.

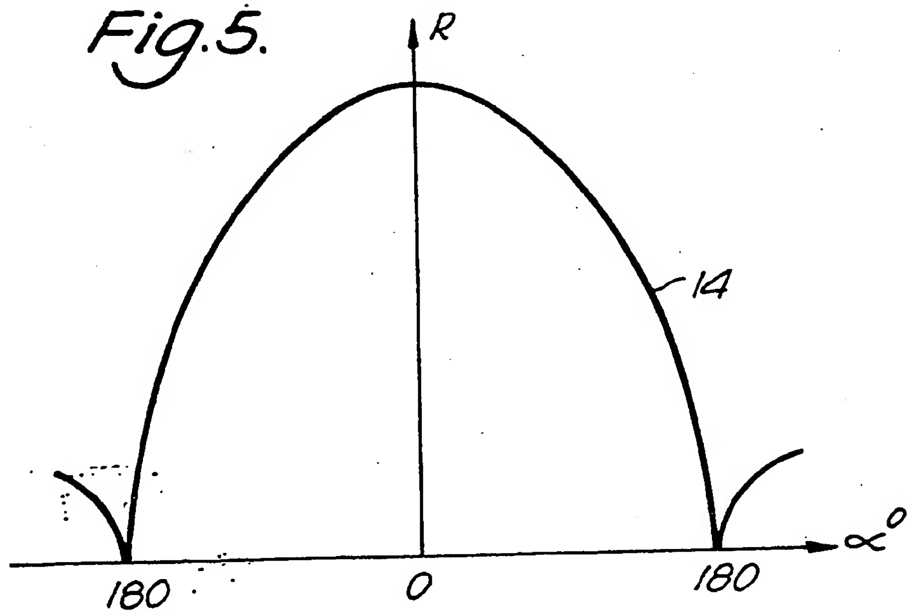


Fig. 6.

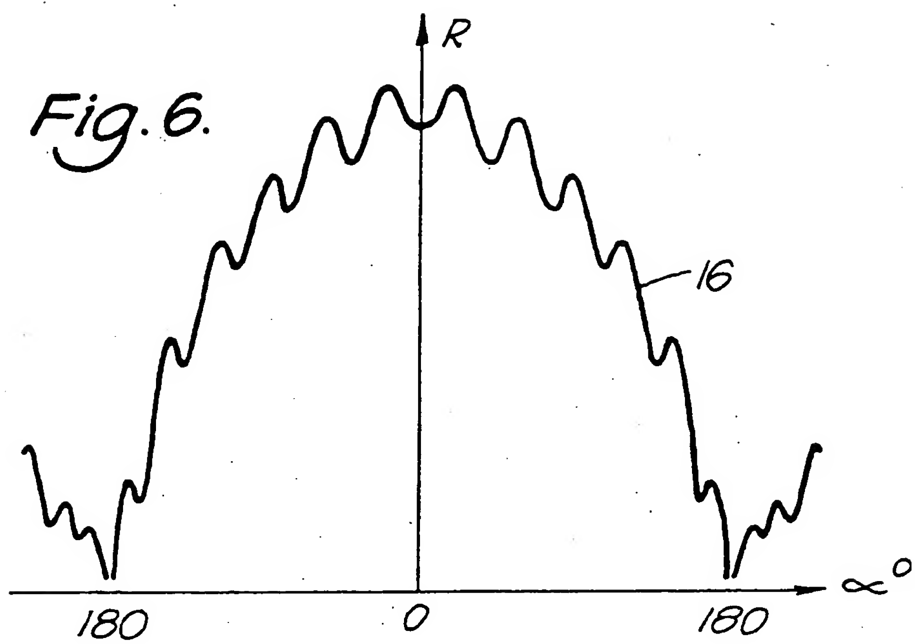
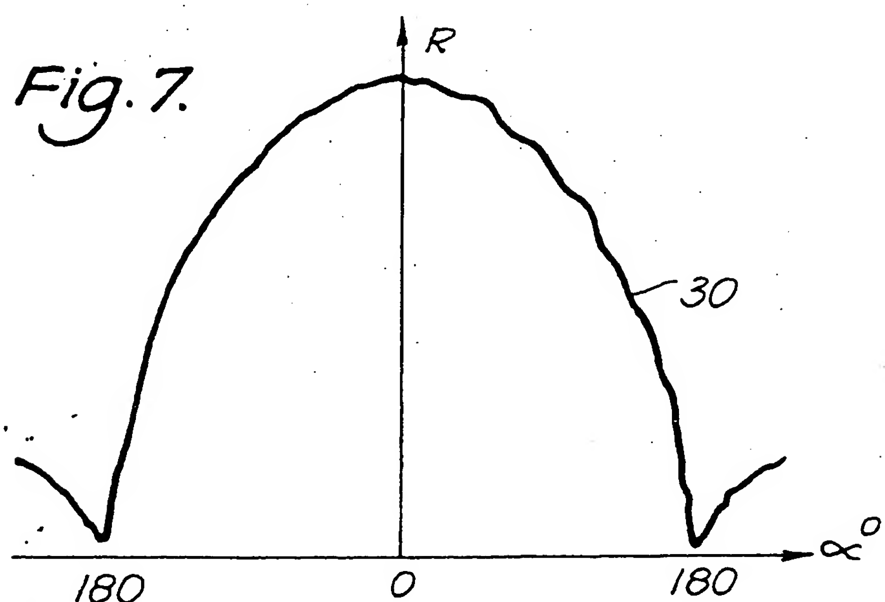


Fig. 7.



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LOW SCATTERING STRUCTURE

The present invention relates to structures for use in electromagnetic fields and in particular to such structures having controllable scattering patterns when excited by incident electromagnetic fields.

When an object is placed in the path of an electromagnetic wave it is excited by the incident wave and re-radiates the energy which it absorbs from the incident wave. The characteristics of the re-radiated energy - its polarisation and distribution in space - are determined both by the nature of the incident wave and by the electrical properties of the scattering obstacle.

For some applications it is required to reduce the disturbance caused to the incident wave to the lowest practical levels, so that the presence of the scattering obstacle may not be detected by changes in the uniformity of the incident wave.

The behaviour of radiation from scattering obstacles has been extensively studied and is well documented. Scattering is greatest when a linear conducting member is placed with its longitudinal axis parallel to the direction of polarisation of the incident wave. Methods of reducing scattering have included covering obstacles with radio-frequency absorbing materials but, whilst reducing the re-radiated or scattered energy, this method also disrupts the uniformity of the incident wave.

In accordance with the present invention there is provided a structure comprising at least two conductive elements in each of which an excitation current flows when the structure is illuminated by an incident electromagnetic field, wherein the

conductive elements are separated by a pre-determined distance, and the impedance characteristics of each conductive element produce a pre-determined shift in the phase of the excitation current relative to the phase of incident electromagnetic field; the predetermined phase shift in each of the conductive elements, and the separation distance between them, being such as to reduce energy radiated by the conductive elements in a pre-selected direction.

By aligning the direction of reduced re-radiated energy with the incident wave direction, the disturbance caused to the incident wave can be substantially minimised.

The conductive elements may be a pair of substantially parallel conductors mounted in a suitable support structure. One of the elements preferably has principally inductive impedance characteristics to introduce a phase lag in the excited current. The other element preferably has principally capacitive impedance characteristics to introduce a phase lead. By careful selection of the impedance characteristics, the scattering due to the supporting structure may be controlled in addition to that from the conductive elements.

Preferably, at least one of the conductive elements is a continuous conductor to allow the structure to also act as a signal path to carry signals having a characteristic frequency below that of the incident field. Such structures may suitably be used in the construction of antenna elements or feed structures in which the scattering properties are controlled to minimise the effect on, for example the radiation patterns of other adjacent antenna elements.

One particular preferred embodiment of the present invention

will now be described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of the scattering pattern of an ideal conductor;

Figure 2 represents a pair of spaced conductors illuminated by an incident electromagnetic field;

Figure 3 is a schematic diagram of the scattering structure of the present invention;

Figure 4 represents one configuration of each of the elements of the scattering structure of Figure 3;

Figure 5 shows the radiation pattern of an antenna having modest directivity;

Figure 6 shows the radiation pattern of the same antenna when the radiated field encounters a scattering obstacle; and

Figure 7 shows the radiation pattern of the same antenna when the radiated field encounters the scattering structure of the present invention.

The basic principle of scattering is illustrated in Figure 1. A substantially perfect conductor 10, extending longitudinally orthogonal to the plane of the paper is illuminated by an incident electromagnetic field I. The incident field I comprises a plane wave travelling in the direction indicated by the arrow 12, having its electrical field line (E - vector) parallel with the axis of the conductor. Illumination by the incident field I excites the conductor 10 which re-radiates or scatters energy in a plane orthogonal to its axis. The

conductor 10 acts as an isotropic source, radiating energy of equal intensity in all directions in the plane, including the direction of the incident field I. Where the E - vector is not parallel to the conductor 10, the pattern of radiated energy distribution will vary but there will still be a component in the direction of the incident field I.

Figures 5 and 6 show the radiation patterns (plotted as relative field strength R against field angle α) for an antenna having modest directivity. In Figure 5 there is no obstacle illuminated by the field radiated by the antenna, and the radiation pattern 14 is a smooth curve. Figure 6 illustrates the disruption of the radiation pattern 16 resulting from a scattering obstacle (such as the conductor 10 of Figure 1) in the path of the radiated field. The energy re-radiated in all directions by the obstacle disrupts the radiation pattern and indicates the presence of an obstacle in the radiated field.

Figure 2 shows a double obstacle comprising a parallel pair of conductors 18, 20 spaced by a distance x arranged as in Figure 1 and again illuminated by an incident field I. The current excited in the two conductors 18, 20 will differ in phase by an amount (ϕ°) determined by their spacing along the incident wave propagation axis. The re-radiated field from the conductor pair 18, 20 will be characteristic of two elements having a spacing x and carrying equal currents with a given phase separation ϕ°. Irrespective of the spacing x, the distribution of scattered energy will have a peak in the forward direction (the direction of the incident wave I) as a consequence of illumination by a travelling wave.

The operation of the low scattering structure of the present invention is illustrated generally in Figure 3. The structure

is in the form of a double obstacle as in Figure 2. The first obstacle 22 is chosen to have an impedance which is largely inductive so that current excited in it has a phase which lags that of the incident wave I by a first angle y^{o}. The second obstacle 24 has a largely capacitive impedance and thus the exitation current phase will lead the phase of the incident wave I by a second angle Z^{o}. By selection of the impedance values of the two conductors 22, 24 the radiated energy distribution may be controlled to provide a minimum in the forward direction, or in any other desired direction. The radiation pattern resulting from the illumination of the structure of Figure 3 is shown in Figure 7. As can be seen, the minimisation of energy re-radiated in the direction of the incident wave greatly reduces disruption of the radiation pattern 30.

A suitable form of each of the two conductors 22, 24 is represented in Figure 4. The inductive conductor 22 is in the form of a helical coil or a meander line in which the conductor describes a series of two dimensional meanders, zig zags, or teeth 26 of any chosen profile. The capacitive conductor 24 comprises a series of short conducting segments 28 whose length, spacing and relative disposition is chosen to provide the required capacitive coupling between the segments 28. In use, the conductors 22, 24 would be positioned in parallel planes separated by a predetermined distance x.

In order to increase the mechanical stability of the inductive element, a number of separate, laterally-spaced conductors may be used, each associated with its corresponding capacitive element. The capacitive element 24 is simply constructed by use of established printed circuit techniques. In one construction of a structure according to the present invention a rectangular tube formed from glass-reinforced plastics

contains the inductive and capacitive elements. The inductive line is formed on one inner face of the tube and the capacitive element on the opposite inner face of the tube. By optimisation of the parameters of the inductive and capacitive scattering elements, the scattering caused by the tube can also be compensated for.

In an alternative construction, the inductive element 22 may be formed from a length of coaxial cable formed into a coil. The co-axial cable may be used to carry RF or other signals.

It is particularly desirable for one of the two conductors (the inductive element 22) to be of continuous form. This allows the structure to be used for construction of antenna elements and feed structures, typically operating at frequencies much lower than that of the illuminated field. Structures constructed in accordance with the present invention can therefore be placed in front of a second antenna and will have a negligible effect upon the far-field radiation pattern of the second antenna.

Devices constructed according to the invention are not limited to antenna structures but could include supports and cabling for other technical equipment. Such structures combine mechanical strength with a conductive path having low scattering.

CLAIMS

1. A structure comprising at least two conductive elements in each of which an excitation current flows when the structure is illuminated by an incident electromagnetic field, wherein the conductive elements are separated by a pre-determined distance, and the impedance characteristics of each conductive element produce a pre-determined shift in the phase of the excitation current relative to the phase of incident electromagnetic field; the predetermined phase shift in each of the conductive elements, and the separation distance between them, being such as to reduce energy radiated by the conductive elements in a pre-selected direction.

2. A structure according to claim 1 in which the pre-selected direction in which radiated energy is minimised is aligned with the direction of the incident electomagnetic field exciting the conductive elements.

3. A structure according to claim 1 or claim 2 further comprising an elongate support structure on which the conductive elements are mounted.

4. A structure according to claim 3 in which the support structure is an elongate tube of non-conductive material inside which the conductive elements are mounted.

5. A structure according to claim 4 in which the tube of non-conductive material is of substantially constant cross-section and the conductive elements mounted therein are spaced apart by a subtantially constant distance.

6. A structure according to any preceding claim in which one of the conductive elements has a largely capacitive impedance.

7. A structure according to any preceding claim in which one of the conductive elements has a largely inductive impedance.

8. A structure according to claim 7 in which the conductive element having a largely inductive impedance is a continuous conductor carrying signals at a frequency substantially below that of the incident electromagnetic field.

9. A structure according to claim 7 or claim 8 in which the conductive element having a largely inductive impedance is a coil of co-axial cable.

10. A structure having controllable scattering substantially as hereinbefore described with reference to the accompanying drawings.

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